Consequences of western disturbance-triggered cooling on the flowering of tree species in the Himalayan Terai region

Currently, the study of plant phenology under the light of different climatic parameters is an impressive tool for climate change assessment studies[1–3]. Thus, a number of studies have been performed globally to understand the interrelationship between these biotic (phenophases) and abiotic (temperature, precipitation, etc.) indices[4–10]. These studies clearly indicate that different phenological events (flowering, fruiting, etc.) are triggered by temperature and precipitation[11–14]. These climatic factors distinctly affect different phenophases at different geo-climatic regions. Therefore the regional–temporal phenological studies along with climatic variability have their own importance[3,15,16]. Keeping these in mind, phenological observations were started in the tropical moist deciduous forest of the Himalayan Terai region from late 2009

Table 1. Shifting of flowering initiation time in selected spring flowering trees

Plant species	Family	Flowering initiation	
		2014	2015
Acacia catechu (L.f.) Willd.	Mimosaceae	Late March	No change
Aegle marmelos (L.) Correa	Rutaceae	Late March	No change
Ailanthus excelsa Roxb.	Simaroubaceae	Early February	Late February
Albizia lebbeck (L.) Benth.	Mimosaceae	Early February	Late February
Artocarpus lakoocha Roxb.	Moraceae	Early January	Early February
Azadirachta indica A. Juss.	Meliaceae	Late March	Early April
Bombax ceiba L.	Bombacaceae	Late January	Early February
Buchanania cochinchinensis (Lour.) Almeida	Anacardiaceaae	Late February	Early March
Butea monosperma (Lam.) Taub.	Papilionaceae	Late February	Late March
Calotropis gigantea (L.) Dryand.	Apocynaceae	Late February	Early March
Carissa carandas L.	Apocynaceae	Late March	No change
Cassia fistula L.	Caesalpiniaceae	Early March	Late March
Dalbergia sissoo Roxb. ex DC.	Papilionaceae	Late March	No change
Desmodium oojeinense (Roxb.) H. Ohashi	Papilionaceae	Late March	No change
Dillenia pentagyna Roxb.	Dilleniaceae	Late March	No change
Ehretia laevis Roxb.	Ehretiaceae	Late January	Late February
Eucalyptus tereticornis Sm.	Myrtaceae	Late January	Early February
Ficus benghalensis L.	Moraceae	Late February	Early March
Guazuma ulmifolia Lamk.	Malvaceae	Early February	Late February
Guidonia tomentosa (Roxb.) Kurz	Salicaceae	Late February	Early March
Heynea trijuga Roxb. ex Sims	Meliaceae	Early February	Early March
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	Late February	Early March
Kavalama urens (Roxb.) Raf.	Malvaceae	Late January	Late February
Lagerstroemia parviflora Roxb.	Lythraceae	Late March	No change
Lannea coromandelica (Houtt.) Merr.	Anacardiaceaae	Late March	No change
Litsea glutinosa (Lour.) Rob.	Lauraceae	Late March	No change
Madhuca longifolia var. *latifolia* (Roxb.) Chev.	Sapotaceae	Late February	Early March
Mallotus nudiflorus (L.) Kulju & Welzen	Euphorbiaceae	Late February	Early March
Mallotus philippensis (Lamk.) Muell.-Arg.	Euphorbiaceae	Late February	Early March
Mangifera indica L.	Anacardiaceaae	Late February	Early March
Melia azedarach L.	Meliaceae	Late February	Early March
Mitragyna parvifolia (Roxb.) Korth.	Rubiaceae	Late March	No change
Moringa oleifera Lamk.	Moringaceae	Early February	Late February
Morus alba L.	Moraceae	Late February	Early March
Murraya koenigii (L.) Spreng.	Rutaceae	Late February	Early March
Phyllanthus emblica L.	Phyllanthaceae	Early March	No change
Pongamia pinnata (L.) Pierre	Papilionaceae	Late March	No change
Psidium guajava L.	Myrtaceae	Early March	Early April
Putranjiva roxburghii Wall.	Euphorbiaceae	Late February	Early March
Salix tetrasperma Roxb.	Salicaceae	Late January	Late February
Schleichera oleosa (Lour.) Merr.	Sapindaceae	Late March	Early April
Shorea robusta Gaertn. f.	Dipterocarpaceae	Late March	No change
Sterculia villosa Roxb.	Sterculaceae	Late February	Early March
Streblus asper Lour.	Moraceae	Late February	Early March
Syzygium cumini (L.) Skeels	Myrtaceae	Late March	No change
Toona ciliata M. Roem.	Meliaceae	Late March	Early April

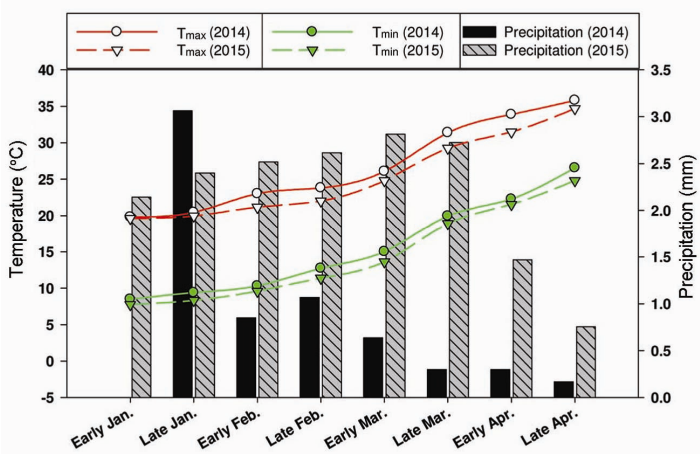

Figure 1. Deviation of mean maximum (T_{max}) and minimum (T_{min}) temperature, and precipitation from 2014 to 2015 (January–April).

to record the temporal behaviour of some selected tree species to complete the knowledge lacunae on phenological information from this eco-region.

The study was conducted at Katerniaghat Wildlife Sanctuary (KWS), a good representative of tropical moist deciduous forest of the Himalayan Terai region, situated in Bahraich district of Uttar Pradesh, India[16]. The study was conducted to observe the initiation and completion period of different phenophases (viz. flowering, fruiting, leafing and leaf-fall) of ten individuals of each species twice a month (first and last week of the month) for five years at three similar microclimatic sites (Kakraha, Murtiha and Nishangarha). A portable meteorological station has also been established in the study area to collect the temperature and rainfall data. Since the starting of data collection from 2009 to 2014, no significant annual variation was recorded in the initiation of phenophases as well as in the temperature and precipitation. However, in the month of February, March and the first half of April in 2015, considerable decrease in mean maximum temperature (1.1–2.4°C) and minimum temperature (0.7–1.7°C) was recorded, along with significant increase in the mean precipitation (0.6–2.4 mm; Figure1). During these months western disturbances are considered the controlling key factor for bringing changes in the temperature and precipitation in the region[17–19] and its hyper and prolonged activity may be one of the main reasons behind this abnormal cooling and higher precipitation rate. As the temperature and precipitation have been considered the triggering agents for flowering events[16,20–22], the decreased temperature and increased precipitation affect the timing of flower initiation. When a comparison of flower initiation period of 2014 was made with 2015, a clear deviation was observed in most of the spring flowering tree species (Table 1). The observation clearly indicates that 32 out of 46 spring flowering trees species considered in the present study, exhibit significant delay in flower initiation. This may be due to their greater sensitivity towards the climate and environment. The flowering of the remaining 14 species was not affected; this may be due to their non or delayed reacting nature against changing climate[23]. This study shows delayed flowering in the tropical moist deciduous forests of the Himalayan Terai region, due to decreased temperature and increased precipitation caused by western disturbances. A detailed study is required to explain the phenological behaviour of those species which are unaffected with decrease in temperature and increase in precipitation.

1. Corlett, R. T. and Lafrankie, J. V., *Climate Change*, 1998, **39**, 439–453.
2. Mezel, A., *Climate Change*, 2002, **54**, 379–385.
3. Moza, M. K. and Bhatnagar, A. K., *Curr. Sci.*, 2005, **89**(2), 243–244.
4. Opler, P. A., Frankie, G. W. and Baker, H. G., *J. Biogeogr.*, 1976, **3**, 231–236.
5. Hilty, S. L., *Biotropica*, 1980, **13**, 292–306.
6. Devineau, J. L., *J. Trop. Ecol.*, 1999, **15**, 497–513.
7. Hamann, A., *J. Ecol.*, 2004, **92**, 24–31.
8. Menzel, A. *et al.*, *Global Change Biol.*, 2006, **12**(10), 1969–1976.
9. Lesica, P. and Kittelson, P. M., *J. Arid Environ.*, 2010, **74**, 1013–1017.
10. Borah, M. and Devi, A., *Trop. Plant Res.*, 2014, **1**(3), 1–12.
11. Borchert, R., Rivera, G. and Hagnauer, W., *Biotropica*, 2002, **34**, 27–39.
12. Primack, D., Imbres, C., Primack, R. B., Milier-Rushing, A. J. and Tredici, P. D., *Am. J. Bot.*, 2004, **91**, 1260–1264.
13. Zhongkui, L., Osbert, J. S., Quansheng, G., Wenting, X. and Jingyun, Z., *Ecol. Res.*, 2007, **22**(3), 507–514.
14. Estrella, N., Sparks, T. H. and Menzel, A., *Climate Res.*, 2009, **39**, 235–248.
15. Karmer, K., *Phenology and Growth of European Trees in Relation to Climate Change*, Bakhuys, The Netherlands, 1997.
16. Bajpai, O., Kumar, A., Mishra, A. K., Sahu, N., Behera, S. K. and Chaudhary, L. B., *Int. J. Bot.*, 2012, **8**(2), 66–72.
17. Pisharoty, P. R. and Desai, B. N., *Indian J. Meteorol. Geophys.*, 1956, **8**, 333–338.
18. Das, M. R., Mukhopadhyay, R. K., Dandekar, M. M. and Kshirsagar, S. R., *Curr. Sci.*, 2002, **82**(11), 1320–1321.
19. Hatwar, H. R., Yadav, B. P. and Rama Rao, Y. V., *Curr. Sci.*, 2005, **88**(6), 913–920.
20. Ashton, P. S., Givnish, T. J. and Appanah, S., *Am. Nat.*, 1988, **132**, 44–66.
21. Williams-Linera, G., *Global Ecol. Biogeogr. Lett.*, 1997, **6**, 115–127.
22. Eamus, D. and Prior, L., *Adv. Ecol. Res.*, 2001, **32**, 113–197.
23. Visser, M. E., van Noordwijk, A. J., Tinbergen, J. M. and Lessells, C. M., *Proc. R. Soc. London, Ser. B*, 1998, **265**, 1867–1870.

ACKNOWLEDGEMENTS. We thank the Director, CSIR-National Botanical Research Institute, Lucknow and Head, Department of Botany, Banaras Hindu University, Varanasi for providing the necessary facilities. Financial support was received from CSIR and DST, Government of India. We also thank the PCCF (Wildlife), Government of Uttar Pradesh, Lucknow for granting permission and the forest staff for logistic support to conduct the study.

Received 1 May 2015; revised accepted 25 August 2015

OMESH BAJPAI[1,2,*]
JITENDRA PANDEY[2]
LAL BABU CHAUDHARY[1]

[1]*Plant Diversity, Systematics and Herbarium Division, CSIR-National Botanical Research Institute, Lucknow 226 001, India*
[2]*Centre of Advanced Study in Botany, Banaras Hindu University, Varanasi 221 005, India*
**For correspondence.*
e-mail: omeshbajpai@gmail.com